Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Environmental Sciences 11 (2011) 63 – 69
Procedia Environmental Sciences

MODM-based Evaluation Model of Service Quality in the Internet of Things

Fan Shaoshuai, Shi Wenxiao✉, Wang Nan, Liu Yan
College of Communication Engineering Jilin University Changchun, China
swx@jlu.edu.cn

Abstract

The Internet of Things (IOT) which is considered to be the next step of the revolution of internet lets us transform everyday objects into smart objects that can understand and react to their environment. For achieving the intelligent service provision in IOT environment depending on the context resource, a mechanism for Quality of Service (QoS) management which can analyze the contexts and employ methods to evaluate QoS is greatly needed. In this paper, a multi-objective decision making (MODM) based evaluation model of service quality is proposed. Both the resource state and the user preferences are taken into consideration in order to improve the reasonableness of the QoS evaluation model. The calculated result of the proposed model can act as a metric for service evaluation and selection.

Keywords: Internet of Things; quality of service; multi-objective decision making; service evaluation

1. Introduction

The Internet of Things (IOT) is a concept that visualizes the vision for bringing the internet even to dummy things. By bringing the internet to dummy things, new services can be created and be used by things, devices and humans. The International Telecommunication Union (ITU) reports suggest that Radio Frequency Identification (RFID) is one of the useful technologies for connecting things. And with the success of RFID technology, the IOT has become popular to emphasize the vision of a global infrastructure of networked physical objects [1, 2].

However, despite the rapid development of RFID technology, many challenging issues need to be solved for supporting effective RFID service provision in the Internet of Things Computing (IOTComp) environment [3]. One of them is how to decide whether the service is loadable for the mobile RFID reader with limited resource and whether the provided service can meet the user’s needs [4].

IOT service infrastructure is also expected to promptly evaluate the quality of services and provide satisfying services for the users depending on the RFID contexts. The context resource, which can provide

doi:10.1016/j.proenv.2011.12.011

intelligent service selection, represents the knowledge of IOTComp environment. The knowledge includes the user preferences, device capability and network state, etc.

The work of this paper focuses on an evaluation model of service quality and its application in intelligent service selection in IOTComp environment. And the rest of this paper is organized as follows: In section II, we discuss the related work and introduce various service evaluation modeling techniques in IOT. In section III, the service controller in IOT in introduced. In section IV, we propose a multi-objective decision making (MODM) based evaluation model of service quality in IOT. In section V, we perform a simulation to verify the result of the proposed evaluation model. In the last section, the conclusions of this paper are made.

2. Related Work

Quality of Service (QoS) model has been studied by many researchers in IOTComp environment. The QoS model can analyze IOTComp contexts and employ methods to compute the value of QoS which acts as a metric for service evaluation and selection. But most previous work focused on the RFID network protocols, middleware, devices reliability, safety and cost, etc. [5-7].

Using analytic hierarchy process method that enables rational decision making by simplifying complicated problems, a selection method that evaluates quality of service was proposed in [8]. A fuzzy logic control-based intelligent agent which applies a fuzzy logic controller to evaluate workload of middleware and executes dynamic load balancing was proposed in [9]. An adaptive service framework which employs a control decision-making system to reduce the consumption of device resource was proposed in [10].

Many factors such as energy cost and load state are used for service evaluation. But the service evaluation should not only consider the resource state and device capability. The user preferences and subjective opinions should be fully taken into consideration for good service evaluation.

3. Service Controller in IOT

The premise of effective service provision is the understanding of the context resource. The context is any information that can be used to characterize the situation of an entity. An entity can be a person, a device, or an object that is considered relevant to the interaction between a user and its application. There are different types of context that can be used in service evaluation, such as energy context, bandwidth context and availability context, etc. And more information can be got by the combination of the contexts.

Because of the computing complexity and mobility of IOT applications, more and more task cannot be finished by a single device. So the target mask must be finished by the cooperation of more than one device. And how to choose a suitable service from all the useable services regardless of user's and object's location is very important in IOT environment.

The service controller in IOT can make use of the user preferences and resource state information which is summarized from many kinds of context resource, and employ the QoS model to evaluate the quality of service. After the QoS is evaluated, the best service can be selected by the service controller to be provided to the user and meet the user's needs. The structure of service controller is shown in Fig. 1.

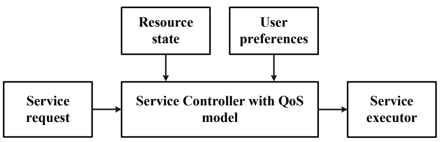

Figure 1 Service controller structure

4. QoS Evaluation Model

When an event happens in the IOT environment, the best service with suitable resource should be chosen to deal with it. Therefore QoS evaluation model is needed for service evaluation and selection.

The QoS evaluation can be regarded as a multi-objective decision making problem [11, 12]. So, in this paper we propose a MODM-based QoS evaluation model to select the best service for the event. Both the resource state and the user preferences are taken into consideration. The flowchart of the proposed model is shown in Fig. 2.

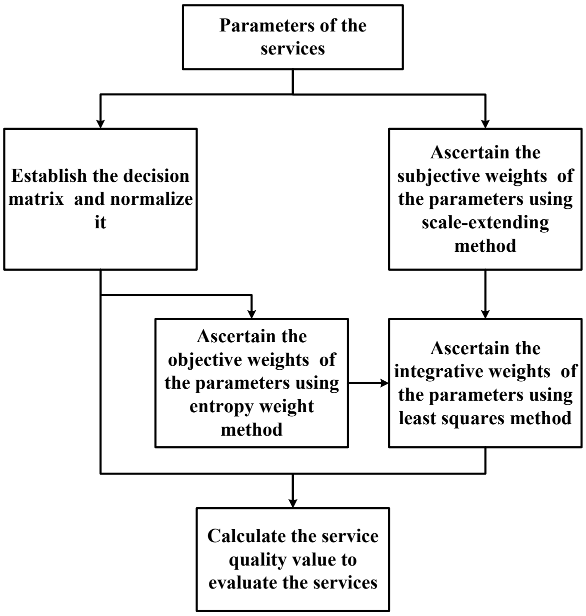

Figure 2 Flowchart of the QoS evaluation model

4.1Establish the Decision Matrix

Considering that there are *m* services to evaluate and *n* parameters of QoS for evaluating, the multi-objective decision matrix can be expressed as

$$A = \left(a_{ij}\right)_{m\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{1}$$

Where a_{ij} represents the value of *j*-th parameter p_j of *i*-th service s_i ; $i = 1,2,\cdots,m$; $j = 1,2,\cdots,n$.

In order to measure the cost-type and benefit-type parameters fairly, the decision matrix *A* should be normalized.

For cost-type parameters

$$b_{ij} = \frac{a_{j\max} - a_{ij}}{a_{j\max} - a_{j\min}} \tag{2}$$

For benefit-type parameters

$$b_{ij} = \frac{a_{ij} - a_{j\min}}{a_{j\max} - a_{j\min}} \tag{3}$$

Where $a_{j\max}$ represents the maximum value of a_{ij} ($i = 1,2,\cdots,m$) and $a_{j\min}$ represents the minimum value of a_{ij} ($i = 1,2,\cdots,m$).

After calculating b_{ij} of two types of parameters, the normalized decision matrix can be expressed as

$$B = \left(b_{ij}\right)_{m\times n} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{bmatrix} \tag{4}$$

4.2Ascertain the Subjective Weights

For the subjective weights of the parameters which reflect the user preferences, we adopt scale-extending method to ascertain the value of the weights.

Firstly, without loss of generality, we consider that the importance ranking of the *n* parameters which is ascertained by the subjective preferences is $p_1 \geq p_2 \geq \cdots \geq p_n$.

Secondly, according to the importance comparison of the parameters, establish the scale value matrix $C = \left(c_{jk}\right)_{n\times n}$ as

$$C = \begin{bmatrix} 1 & r_1 & r_1 r_2 & \cdots & r_1 r_2 \cdots r_{n-1} \\ \frac{1}{r_1} & 1 & r_2 & \cdots & r_2 r_3 \cdots r_{n-1} \\ \frac{1}{r_1 r_2} & \frac{1}{r_2} & 1 & \cdots & r_3 r_4 \cdots r_{n-1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{1}{r_1 r_2 \cdots r_{n-1}} & \frac{1}{r_2 r_3 \cdots r_{n-1}} & \frac{1}{r_3 r_4 \cdots r_{n-1}} & \cdots & 1 \end{bmatrix} \tag{5}$$

Where r_i represents the scale value of the comparison of p_i and p_{i+1}.

The meaning of each scale value is shown in Table I.

Table 1 The Meaning of Each Scale Value

Scale value	meaning
1	p_i is close to p_{i+1}
1.2 (or 1/1.2)	p_i is a little more (or less) important than p_{i+1}
1.4 (or 1/1.4)	p_i is much more (or less) important than p_{i+1}
1.6 (or 1/1.6)	p_i is greatly more (or less) important than p_{i+1}
1.8 (or 1/1.8)	p_i is absolutely more (or less) important than p_{i+1}

Finally, calculate the vector of the subjective weights $\omega = (\omega_1, \omega_2, \cdots, \omega_n)^{\mathrm{T}}$, where the subject weight ω_j of the *j*-th parameter is calculated as

$$\omega_j = \left(\sum_{k=1}^{n} c_{jk}\right)^{1/n} \Bigg/ \sum_{k=1}^{n}\left(\sum_{l=1}^{n} c_{kl}\right)^{1/n} \tag{6}$$

4.3Ascertain the Objective Weights

For the objective weights of the parameters which reflect the resource state, we adopt entropy weight method to ascertain the value of the weights.

According to the normalized decision matrix $B = (b_{ij})_{m\times n}$ and the information theory, the entropy of information H_j of parameter p_j can be calculated as

$$H_j = -(\ln m)^{-1} \sum_{i=1}^{m} h_{ij} \ln h_{ij} \tag{7}$$

Where $h_{ij} = b_{ij} \Big/ \sum_{i=1}^{m} b_{ij}$ and $h_{ij} \ln h_{ij}$ is set to zero when $h_{ij} = 0$.

Then calculate the vector of the objective weights $\mu = (\mu_1, \mu_2, \cdots, \mu_n)^{\mathrm{T}}$, where the object weight μ_j of the *j*-th parameter is calculated as

$$\mu_j = (1 - H_j) \Bigg/ \left(n - \sum_{k=1}^{n} H_k\right) \tag{8}$$

4.4Evaluate the Services

In order to take both the user preferences and the resource state into consideration, the weights of the parameters should be chosen eclectically according to the subjective and objective weights. Therefore, least squares method is used to calculate the vector of the integrative weights $W = (w_1, w_2, \cdots, w_n)^{\mathrm{T}}$.

The least squares method can be expressed as

$$\begin{cases} \min f(W) = \sum_{i=1}^{m}\sum_{j=1}^{n} \left\{ \left[(\omega_j - w_j) b_{ij}\right]^2 + \left[(\mu_j - w_j) b_{ij}\right]^2 \right\} \\ \text{s.t.} \quad \sum_{j=1}^{n} w_j = 1 \\ \qquad w_j \ge 0 \end{cases} \tag{9}$$

Then the services can be evaluated as

$$Q_i = \sum_{j=1}^{n} W_j b_{ij} \tag{10}$$

The service with higher quality value Q is better.

5. Simulation and Analysis

In this paper, the events we considered are communication events in IOT environment. And the ways of service include Object-to-Internet-to-Human (OIH), Human-to-Internet-to-Object (HIO), Object-to-Internet-to-Object (OIO) and Object-to-dedicated IOT infrastructure-to-Object (OIOTO).

The parameters we considered to evaluate a service include battery energy cost R_E , CPU cost R_C , memory usage R_M , user-friendly R_U and network bandwidth usage R_B . Obviously, R_E , R_C , R_M and R_B are cost-type parameters, and R_U is a benefit-type parameter.

When an event happens, the proposed QoS evaluation model can be used to select the best service for the event.

Take en event for example, the normalized decision matrix that has been calculated is

$$B = \begin{bmatrix} 1 & 1 & 0 & 0.2156 & 0.3684 \\ 0.9940 & 0.4547 & 0.0082 & 1 & 1 \\ 0 & 0.3815 & 0.3668 & 0.0226 & 0.1674 \\ 0.9940 & 0 & 1 & 0 & 0 \end{bmatrix}.$$

We consider that the importance ranking of the five parameters is $R_E > R_C = R_M > R_U > R_B$; r_1 =1.6, r_2 =1, r_3 =1.4 and r_4 =1.2.

The scale value matrix that has been calculated is

$$C = \begin{bmatrix} 1 & 1.6 & 1.6 & 2.24 & 2.688 \\ 1/1.6 & 1 & 1 & 1.4 & 1.68 \\ 1/1.6 & 1 & 1 & 1.4 & 1.68 \\ 1/2.24 & 1/1.4 & 1/1.4 & 1 & 1.2 \\ 1/2.688 & 1/1.68 & 1/1.68 & 1/1.2 & 1 \end{bmatrix}.$$

The result of the vector of the subjective weights is $(0.2226, 0.2026, 0.2026, 0.1894, 0.1827)^T$.

The result of the vector of the objective weights is $(0.2944, 0.1400, 0.2076, 0.2056, 0.1525)^T$.

The result of the vector of the integrative weights is $(0.2585, 0.1713, 0.2051, 0.1975, 0.1676)^T$.

The result of quality value is shown in Table 2.

Table 2 Result Of Quality Value

Name of Service	Quality Value
OIH	0.5341
HIO	0.7016
OIO	0.1731
OIOTO	0.4620

From the result of quality value, we can see the ranking of the four IOT Communication ways. When this event is triggered, the ranking of the quality of service is HIO>OIH>OIOTO>OIO, and HIO is the best way of service for this event.

6. Conclusions

This paper proposes a multi-objective decision making based evaluation model of service quality to select the best service for the event in the Internet of Things. The proposed model adopts scale-extending method and entropy weight method to calculate the subjective and objective weights of the service parameters. Meanwhile, least squares method is used to choose them eclectically. Both the resource state and the user preferences are taken into consideration in order to improve the reasonableness of the service evaluation. The result of simulation shows that the proposed model can act as a metric for service evaluation and selection effectively.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (No. 60972028).

References

[1]G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, “Smart objects as building blocks for the internet of things,” IEEE Internet Computing, 2010, vol. 14, pp. 44-51.

[2]E. Welbourne, L. Battle, G. Cole, K. Gould, and K. Rector, et al, “Building the internet of things using RFID: the RFID ecosystem experience,” IEEE Internet Computing, 2009, vol. 13, pp. 48-55.

[3]G. Pujolle, “An autonomic-oriented architecture for the internet of things,” IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing, 2006, pp. 163-168.

[4]G. Venkataramani and S. Gopalan, “Mobile phone based RFID architecture for secure electronic payments using RFID credit cards,” The Second International Conference on Availability, Reliability and Security, 2007, pp. 610-620.

[5]G. Ferrari, F. Cappelletti, and R. Raheli, "Simple performance analysis of multiple access RFID networks based on thebinary tree protocol," International Journal of Sensor Networks, 2008, vol. 4, pp. 194-208.

[6]C. Ko, S. Roy, J. R. Smith, H. W. Lee, and C. H. Cho, “RFID MAC performance evaluation based on ISO/IEC 18000-6 type C,” IEEE Communications Letters, 2008, vol. 12, pp. 426-428.

[7]N. Ahmed and U. Ramachandran, "Reliable framework for RFID devices," Proceedings of the 5th Middleware Doctoral symposium, 2008, pp. 1-6.

[8]G. Oh, D. Y. Kim, S. I. Kim, Sung and Y. Rhew, “A quality evaluation technique of RFID middleware in ubiquitous computing,” 2006 International Conference on Hybrid Information Technology, 2006, vol. 2, pp.730-735.

[9]S. H. Jang and J. S. Lee, “Fuzzy logic control-based load balancing Agent for distributed RFID systems,” Advanced Intelligent Computing Theories and Applications, 2008, vol. 5226, pp. 653-660.

[10] Liu Jianhua and Tong Weiqin, “Adaptive service framework based on grey decision-making in the internet of things,” 2010 6th International Conference on Wireless Communications, Networking and Mobile Computing, 2010.

[11] Lin Qining, Decision Analysis. Beijing: Publishing House of Beijing University of Posts and Telecommunications, 2005.

[12] Shi Wenxiao, Zhao Song, Fan Shaoshuai and Sun Chao, “Multi-objective decision making based access selection algorithm in heterogeneous wireless networks,” Journal of Jilin University Engineering and Technology Edition, in press.